LA-UR-80-2371

TITLE: MODELS FOR POSITIVE MUON DEPOLARIZATION IN SPIN GLASSES FOR ZERO EXTERNAL FIELD

MASTER

AUTHOR(S): M. Leon

SUBMITTED TO: Second International Topical Meeting on Muon Spin Rotation, Vancouver, B.C., August, 1980

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545
An Affirmative Action/Equal Opportunity Employer

UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

MODELS FOR μ^+ DEPOLARIZATION IN SPIN GLASSES FOR ZERO EXTERNAL FIELD*

M. Leon

Los Alamos Scientific Laboratory
Los Alamos, NM 87545 USA

In this paper we consider models for μ^+ depolarization in spin-glass systems with zero external field. The muon polarization as a function of time is found most simply by considering the classical expression for the z-component of a precessing spin:

$$\sigma_z(t) = \cos^2\theta + \sin^2\theta \cos(Ht) \quad , \qquad (1)$$

where θ is the angle between the local field H and the z-axis (which is the beam polarization direction); the units of H are such that the precession frequency of the muon $\omega = H$. Averaging over the possible directions of H gives

$$\langle \sigma_z(t) \rangle_\theta = \frac{1}{3} + \frac{2}{3} \cos(Ht) \quad . \qquad (2)$$

The distribution in field magnitude from the randomly distributed paramagnetic impurities is Lorentzian[1]:

$$p(H) = \frac{a}{\pi^2} H^2/(H^2 + a^2)^2 \quad ; \qquad (3)$$

averaging over this field distribution gives for the static polarization function

$$P_z^L(t) = \langle \sigma_z(t) \rangle_{\theta,H} = \frac{1}{3} + \frac{2}{3}(1 - at)e^{-at} \quad . \qquad (4)$$

Note that, in contrast to the nuclear spin case (Gaussian field distribution[2]),

$$P^{\mu}_{L}(t) = \frac{1}{3} + \frac{2}{3}(1 - \Delta^2t^2)e^{-\Delta^2t^2/2} \quad , \tag{5}$$

$P^{\mu}_{L}(t)$ has a non-vanishing slope for $t = 0$. This is because $p(H)$ (Eq. 3) falls off very slowly for large H; the large fields come from the μ^+ being very close to a paramagnetic ion. (In reality, these fields must be bounded by the field at the μ^+ site closest to an ion; we will discuss the consequences of this fact elsewhere.)

The effect of fluctuations in time of the field at the μ^+ site (or of muon hopping) can be calculated rather simply using the method of Kehr et al.[3]. If following the treatment of Hayano et al.[2] for nuclear spins we use the Strong Collision Model (SCM), which neglects correlations in the field distribution before and after a fluctuation, we find the polarization functions $P_L(t)$ shown in Fig. 1. While the return to $\frac{1}{3}$ at large t is damped out as expected as the

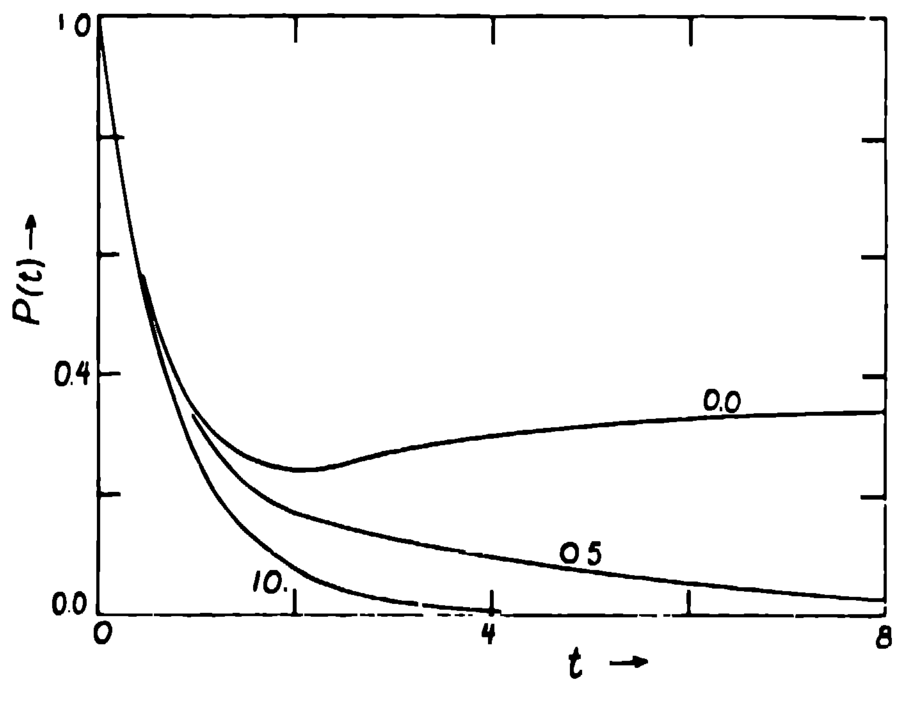

Fig. 1 Zero-field μ^+ polarization as a function of time according to the SCM, for the values of fluctuation rate marked. The field inhomogeneity parameter $a = 1$.

fluctuation rate ν is increased, there is <u>no</u> motional narrowing. This happens because after each fluctuation the steep initial slope of $P_L^{\mu}(t)$ is brought into play. In contrast, in the nuclear spin case, the zero initial slope of $P_L^{N}(t)$ applies at each step, bringing about the motional narrowing (see Hayano et al.[2]).

The steep initial slope of $P_L^{\mu}(t)$ corresponds to the full range of fields being accessible to the μ^+ at each step. However, in the case of spin glasses with temperature T near T_g, where the muon is assumed to be stationary while the local field fluctuates, this is clearly unrealistic; strong fields exist only near a paramagnetic ion and not at most μ^+ sites. A given μ^+ can experience only a limited range of fields, and a not unreasonable simplification is that only the <u>direction</u> of the field changes, not its magnitude. This and the additional assumption that the orientations of the field before and after the fluctuation are uncorrelated define what we call the Weak Collision Model (WCM).

To implement the WCM, we first solve the dynamics (using the method of [illegible] et al.[2]) for a fixed field magnitude (thus using Eq. [illegible] instead of Eq. [illegible]) and then average over all fields. As we see from Fig. [illegible], [illegible]

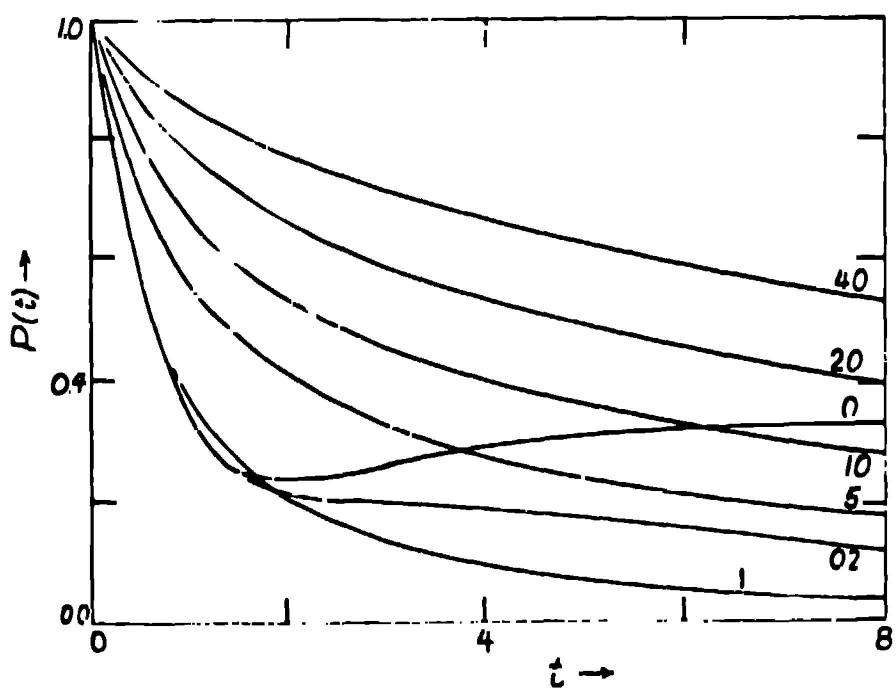

Fig. [illegible] The same as Fig. [illegible], but according to the WCM.

averaging in this way changes $P_L(t)$ very drastically; the WCM results do exhibit the expected motional narrowing. Furthermore, the WCM polarization functions are qualitatively similar to those of Uemura et al.[4], who use the Gaussian results of ref. 2 with a certain weighting factor.

It is interesting to note that for the nuclear spin case, the SCM and WCM results are qualitatively similar. This is because both $P_G^{\nu}(t)$ and $\langle \sigma_z(t) \rangle_{\mu}$ have vanishing slope at $t = 0$.

For small ν and large t all five models give

$$P(t) = \frac{1}{3} \exp(- \frac{2}{3} \nu t). \qquad (6)$$

For large ν all the models except the Gaussian SCM yield non-exponential, and different, functions of t. It will be interesting to look for deviations from exponential behavior in the data.

Finally, we wish to emphasize that both ν and the field inhomogeneity parameter a are physically interesting parameters to measure as functions of temperature T. In particular since in the spin-glass temperature region we expect each paramagnetic ion to have magnetization proportional to the local internal field divided by T, we should have

$$a \approx H_m/T,$$

H_m being the mean internal field. Thus, μSR experiments should give rather direct measurements of $H_m(T)$.

*Supported by the U.S. [illegible]

REFERENCES

1. R. Rivier and E. Adkins, in Amorphous Magnetism, eds. H. [illegible] Hooper and A. M. deGraaf (Plenum, New York, [illegible]) p. [illegible].
2. R. S. Hayano et al., Phys. Rev. B[illegible] ([illegible]) [illegible].
3. F. W. Fehr et al., Hyp. Int. [illegible] ([illegible]) [illegible].
4. Y. J. Uemura et al., to be published.